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Identifying Specific Economic Refrac Candidates in the Eagle Ford and Southern Midland Basin

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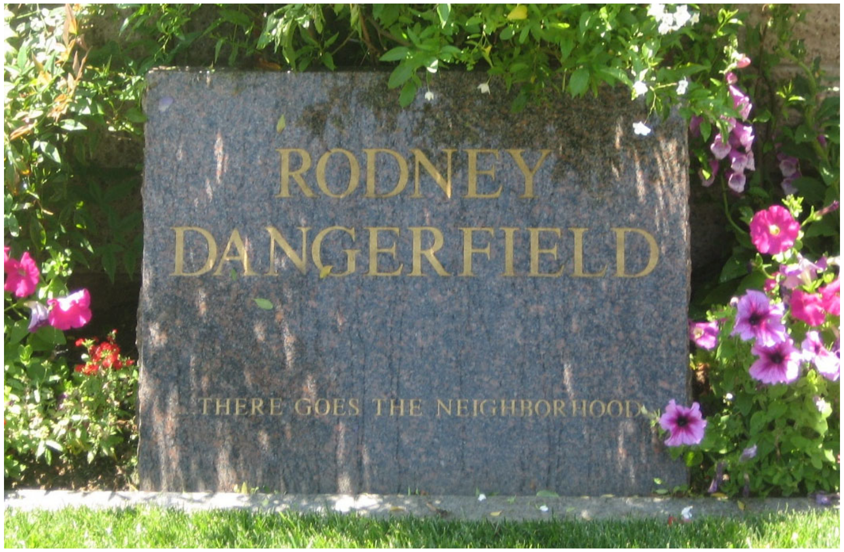
What do Refracs and Rodney Have in Common?

- Last two down cycles (2009 and 2015) saw an increase in refrac papers, the majority of them recommending diverters[1]
- Poor results from these (PLA, ball sealers, etc.) earned refracs very little respect
  - 58 well sample average <2015: average of 1136 open perforations to divert in each well!
  - Ref 1 finding-2000 ft max diverter length
- From 2017 on mechanical isolation methods were finally accepted, isolation results excellent
- Unfortunately the engineers that saw these disasters are now asset managers and above!



[1]SPE 174844 ATCE 2015

Executive Summary

- The study evaluated 327 total producing wells and 159 openhole well logs in the South Texas Eagle Ford condensate window and the Southern Midland Basin Wolfcamp organic shale
- The economics were run using the February 15, 2021 NYMEX strip ($56.66)
  - Most candidates had strong economics at the lower Dec 2020 strip ($46.18)
- All production estimates and costs assume “best practices” which are XLE, close cluster spacing, and expandables for the highest cluster efficiency at the lowest cost
- The study identified 72 wells in the Eagle Ford and 43 wells in the Midland basin with predicted IRRs over 25%
  - Eagle Ford P50 IRR 110% with a $3.74 million NPV10
  - Southern Midland Basin P50 IRR 54% with a $4.7 million NPV10

Executive Summary (contd)

- These rates of return and NPVs are highly competitive with new well results at +/- 2/3 the cost of a new well
- Refracs present a unique opportunity to maintain production levels during a period when most operators are dealing with slim capital budgets
- Two recent studies have shown a strong correlation between cluster spacing alone and recovery factors, results on the following slide
- Both areas have a large number of wide cluster spacing wells that have limited SRVs and large volumes of stranded hydrocarbons, over 9000 wells with over 40 ft spacing for both areas
- Eagle Ford first lateral 2008, Southern Midland Basin 2009
  - EFS 2011 average cluster spacing 72 ft
  - SMB 2011 average cluster spacing 116 ft
  - Current “best practices” +/- 15 ft

Recovery Factor vs Cluster Spacing

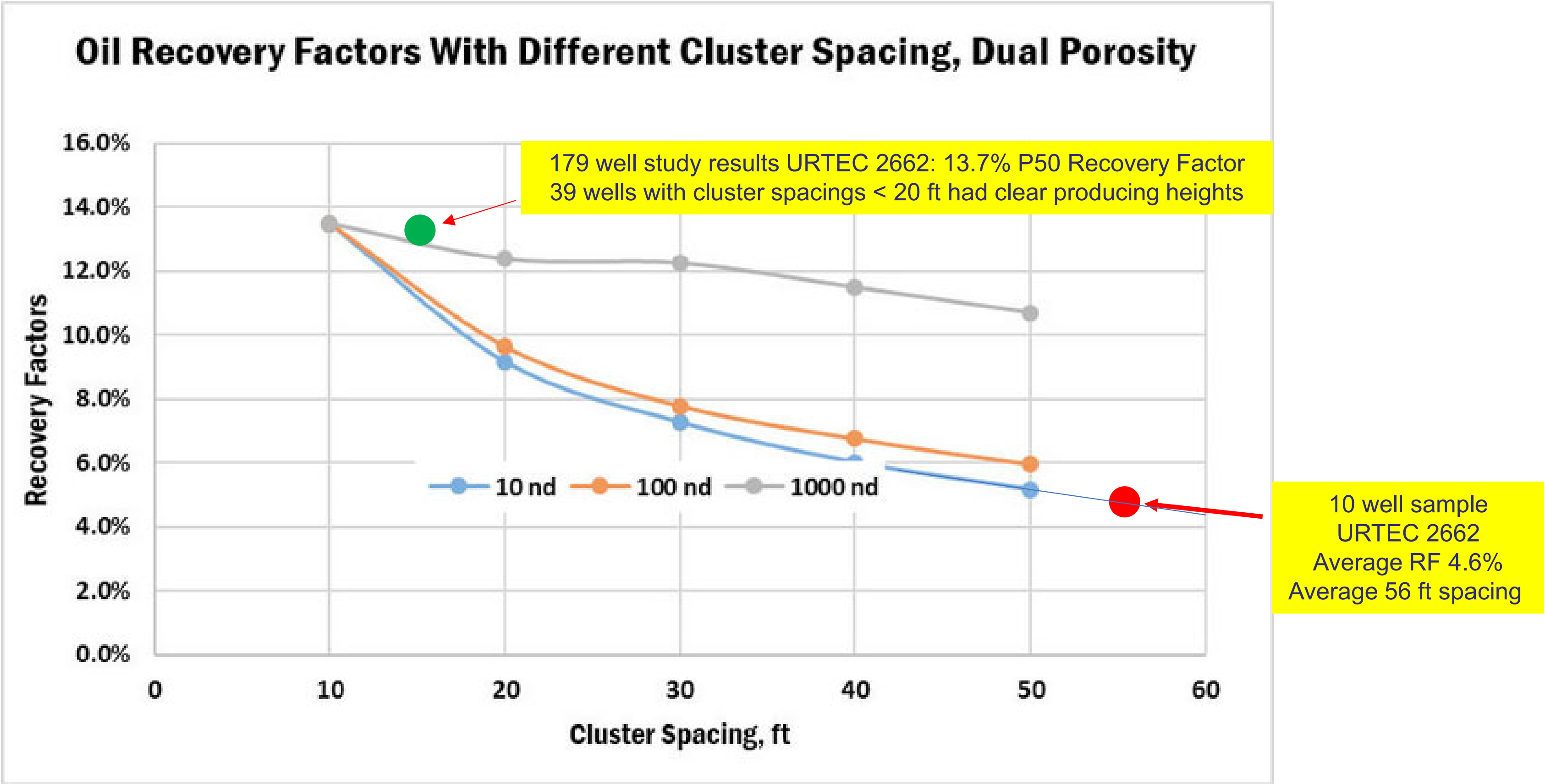


Fig. 10—Recovery efficiency based upon the dual-porosity model at the end of year 30.

Simulations Xiong et al SPE 199721 2020 HFTC

Eagle Ford Pressure Monitor Well Data

Producing Well Gen I Frac 50 ft Cluster Spacing

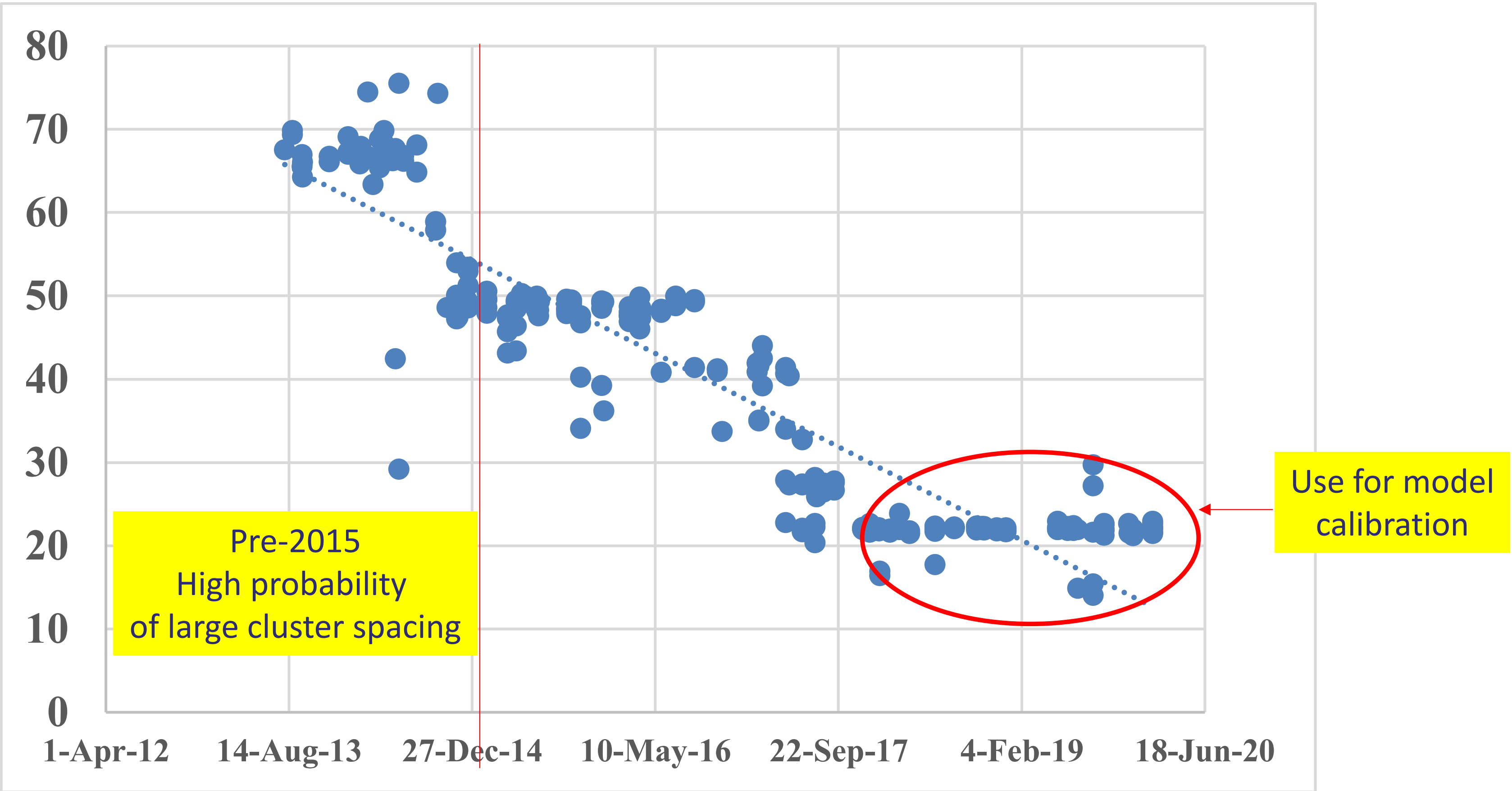
Pressure Monitor Well 70 ft Away Drilled +/- 4 yrs later

■ = depleted area in offset pressure monitoring well (width of SRV)

7.5 ft of lateral drainage (SRV width) observed in monitor well
85% of rock producing almost zero with 50 ft cluster spacing

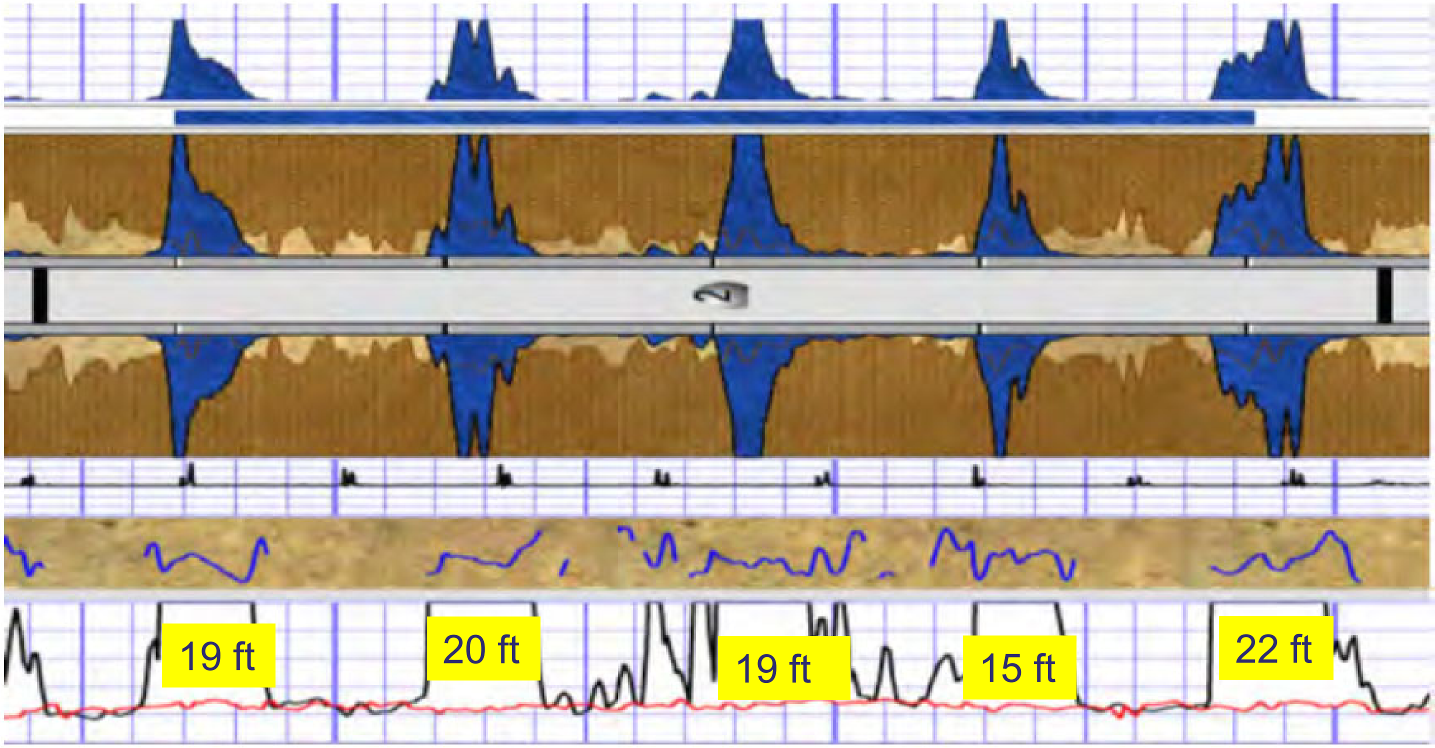
Ref: COP presentation Oct 2018 SPE/Icota Refrac Workshop (slides not released)

EFS Cluster Spacing vs Completion Date



SPE 144326 (2011)

Wolfcamp 50 ft Cluster Spacing Tracer Width



60% of stage not stimulated with 50 ft spacing
Predicted recovery factor from SPE 199721 6%
Detailed reservoir study (URTEC 2434) indicated 7.4%

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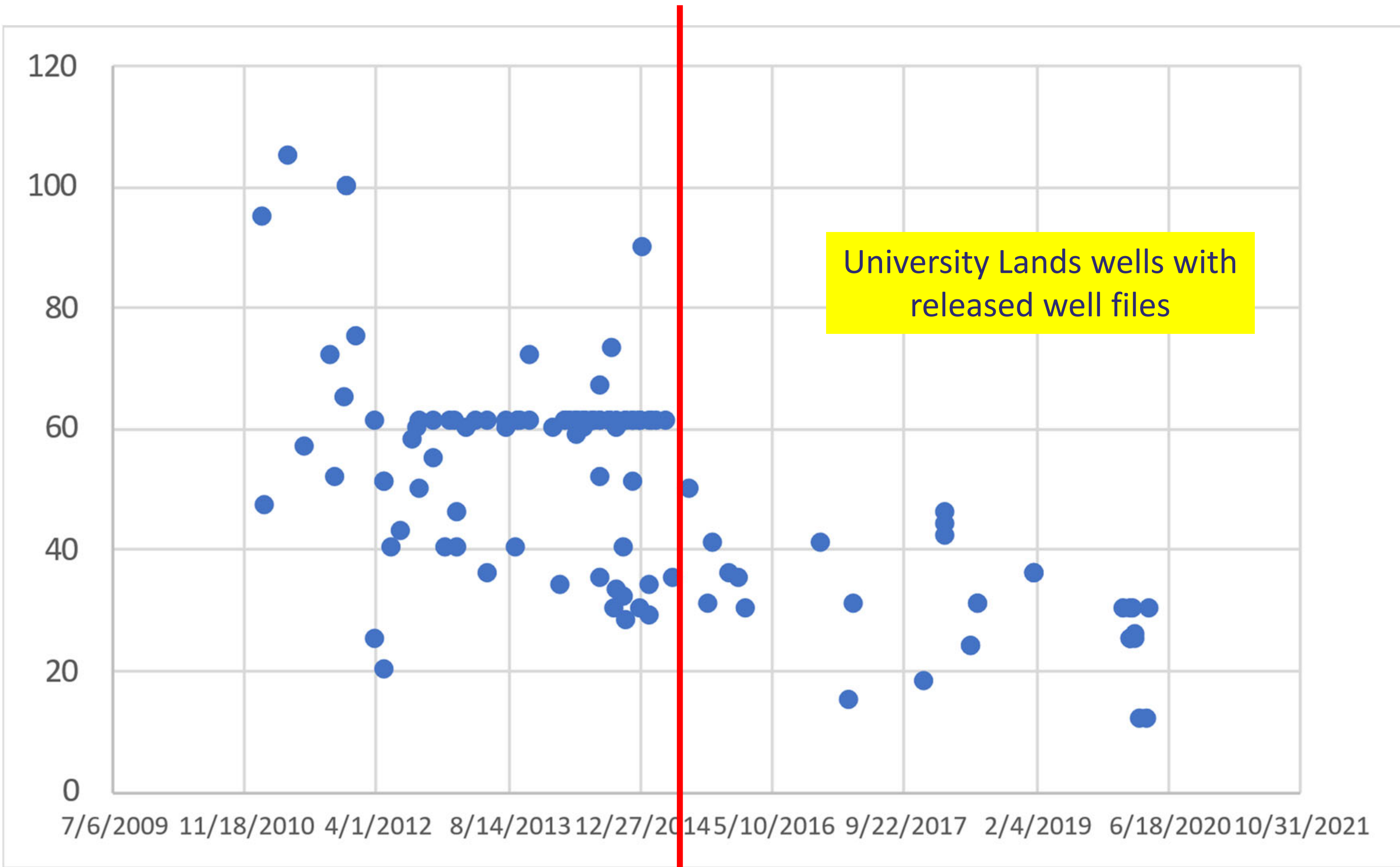
URTEC paper 2902960 Reagan County HFTS

S Midland Basin Cluster Spacing vs Completion Date



Refrac Primary Execution Challenges

- Control fracture entry points to stimulate as close to 100% of the new rock
- Execute a premium optimized frac at the lowest cost per barrel or MCF possible using “best practices”
- XLE and expandable liners will maximize SRV at the lowest cost
  - Higher pump rates with the larger ID expandable liners can result in longer stage lengths and fewer stages
  - $3.5 million AFE assumes XLE and expandable use
  - Once liner is installed the refrac treatment is identical to a new well completion and conventional plug and perf operations can begin
    - XLE will ensure high cluster efficiency (85-90%) even with longer stages (see next slide from SM fiber optic study)
    - High cluster efficiency is assumed in all of the economic analysis scenarios

25% Stage Length Increase vs Active Clusters

- Stage spacing increased 25% with no evidence of performance degradation when using XLE
- Optimal initial perforation friction is 2,000 – 3,000 psi (C_d = 0.7)
- Equal-entry hole perforating charges performed as advertised
- Intrastage diverter drops do not create new fracture initiation points, but can effectively redistribute fluid and proppant among active clusters

Fiber optic temperature used for active clusters

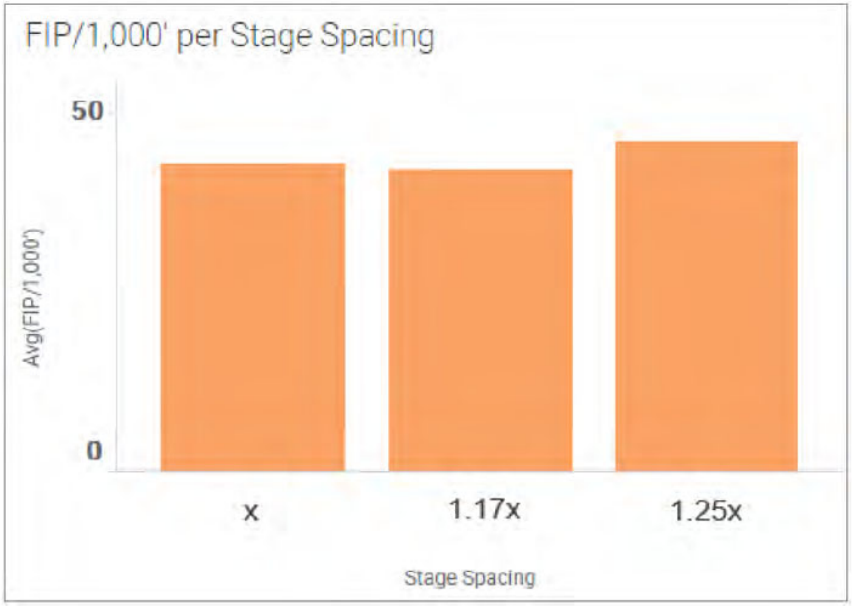


Figure 8—Average fracture initiation points normalized per 1,000' of lateral for different stage spacing designs.

SPE 199712 SM 2020 HFTC

Volume to 1st Response in Offset for XLE Validation

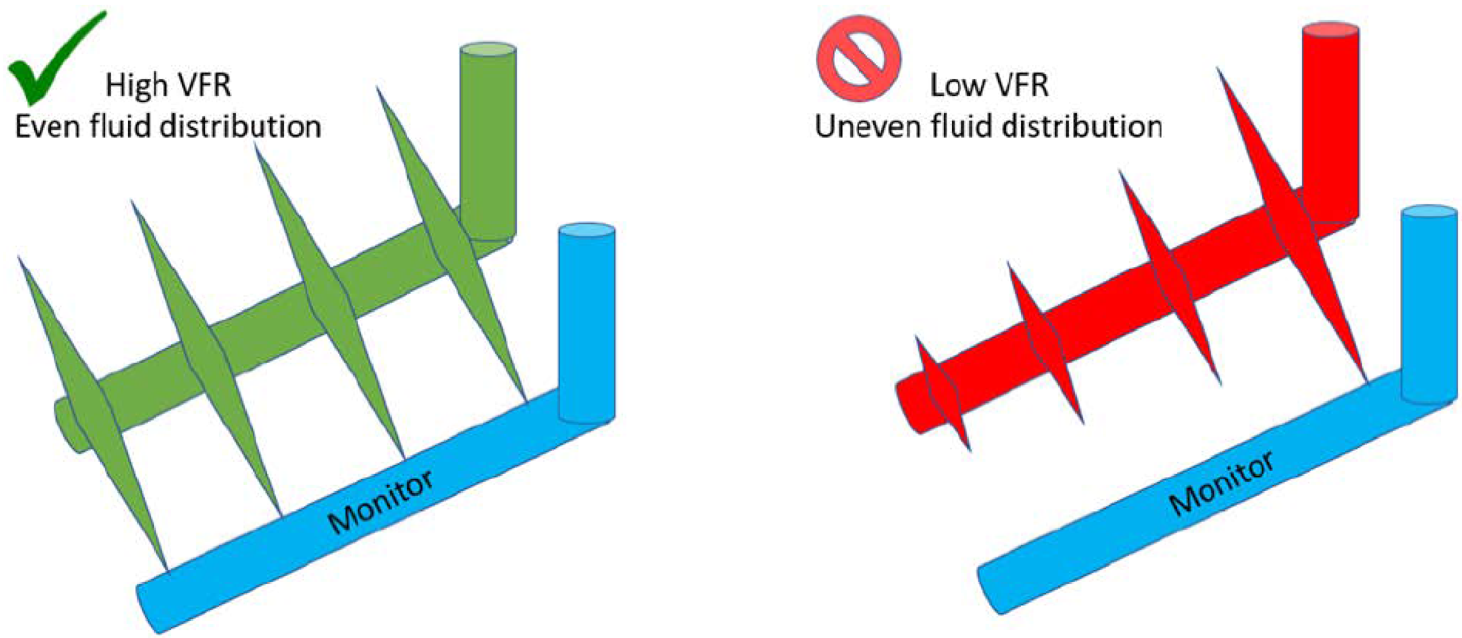


Figure 3—Volume to First Response (VFR) impact on fracture geometry.

XLE Validation with Offset Pressure Monitoring

Low Delta P =
Early response in offset well
Uneven flow into clusters with "runaway" fracs in lower stress clusters

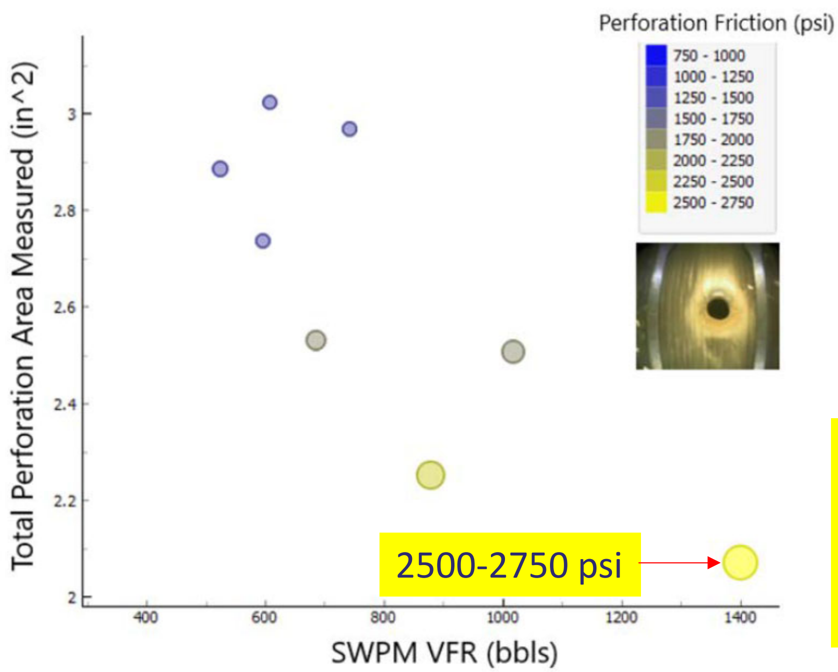


Figure 9—Cross-plot of total perforation area versus volume to first response (VFR) from Sealed Wellbore Pressure Monitoring (SWPM). Each point represents one stage. Points are sized and colored by perforation friction, all of the stages are from one well. The perforation friction is calculated using measured diameters.

Proof that XLE works!

High Delta P =
Delayed response in offset well (close to uniform response across stage)

SPE 199731

XLE vs Conventional Perforating Cluster Efficiency

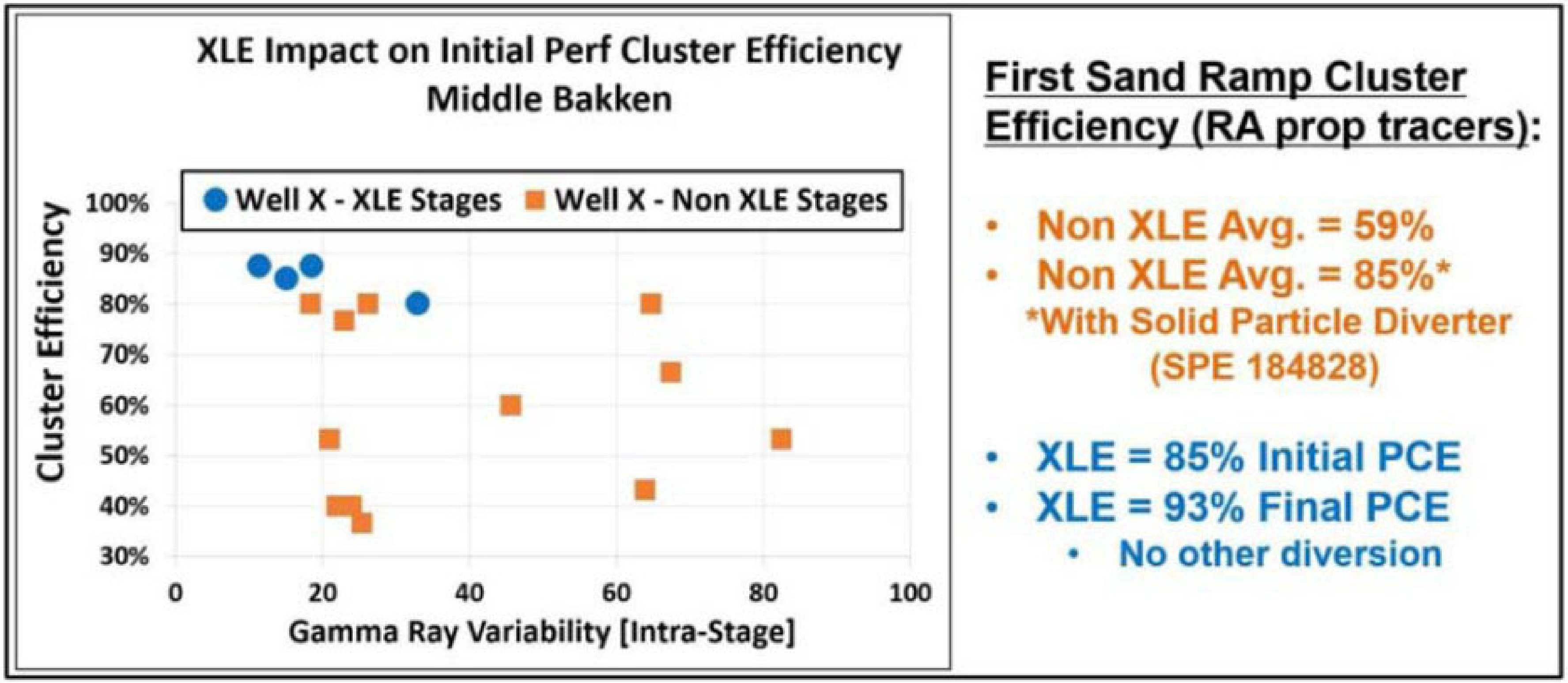
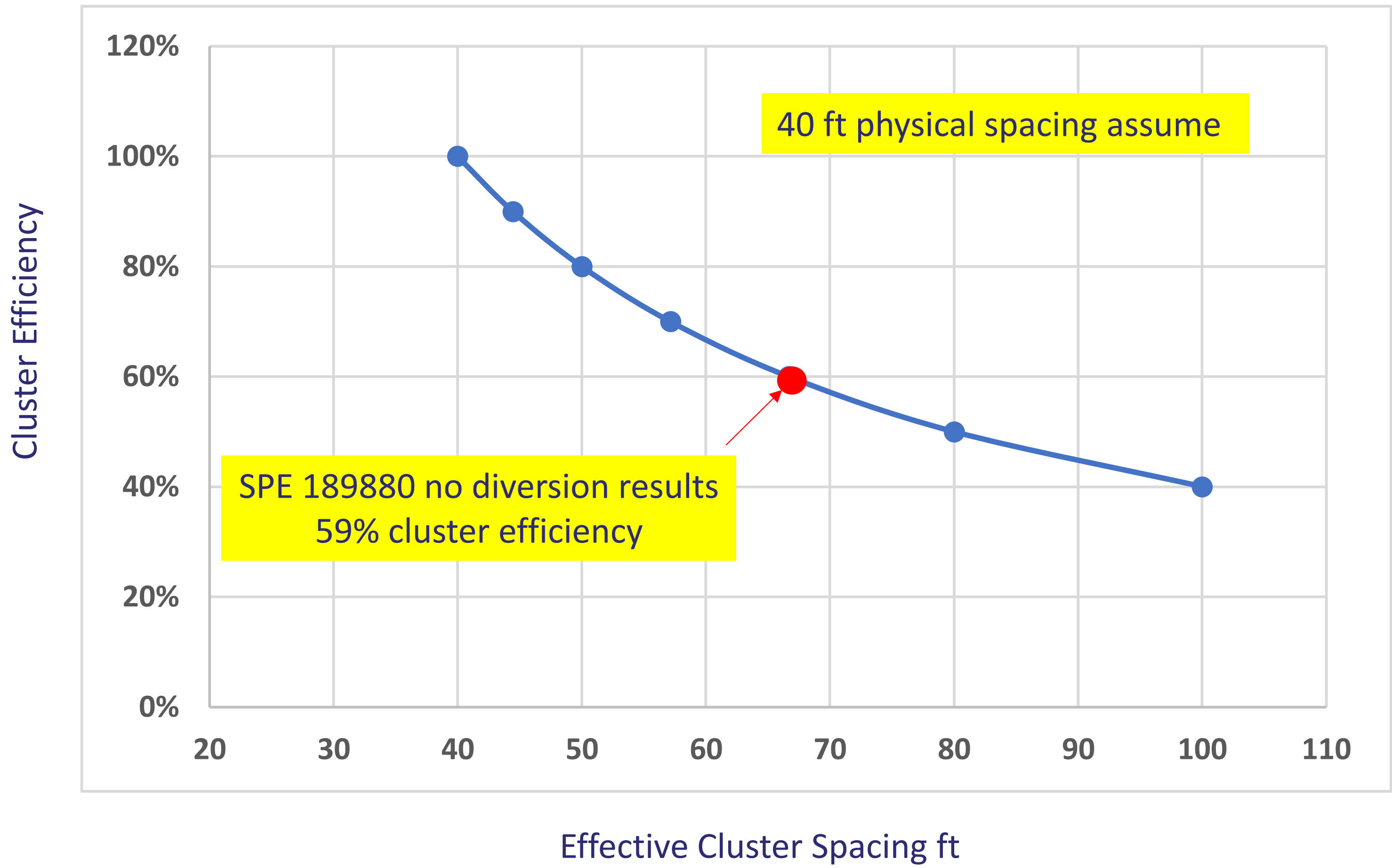


Figure 9—Perforation cluster efficiency (PCE) comparing stages with XLE vs non-XLE stages for Well X.

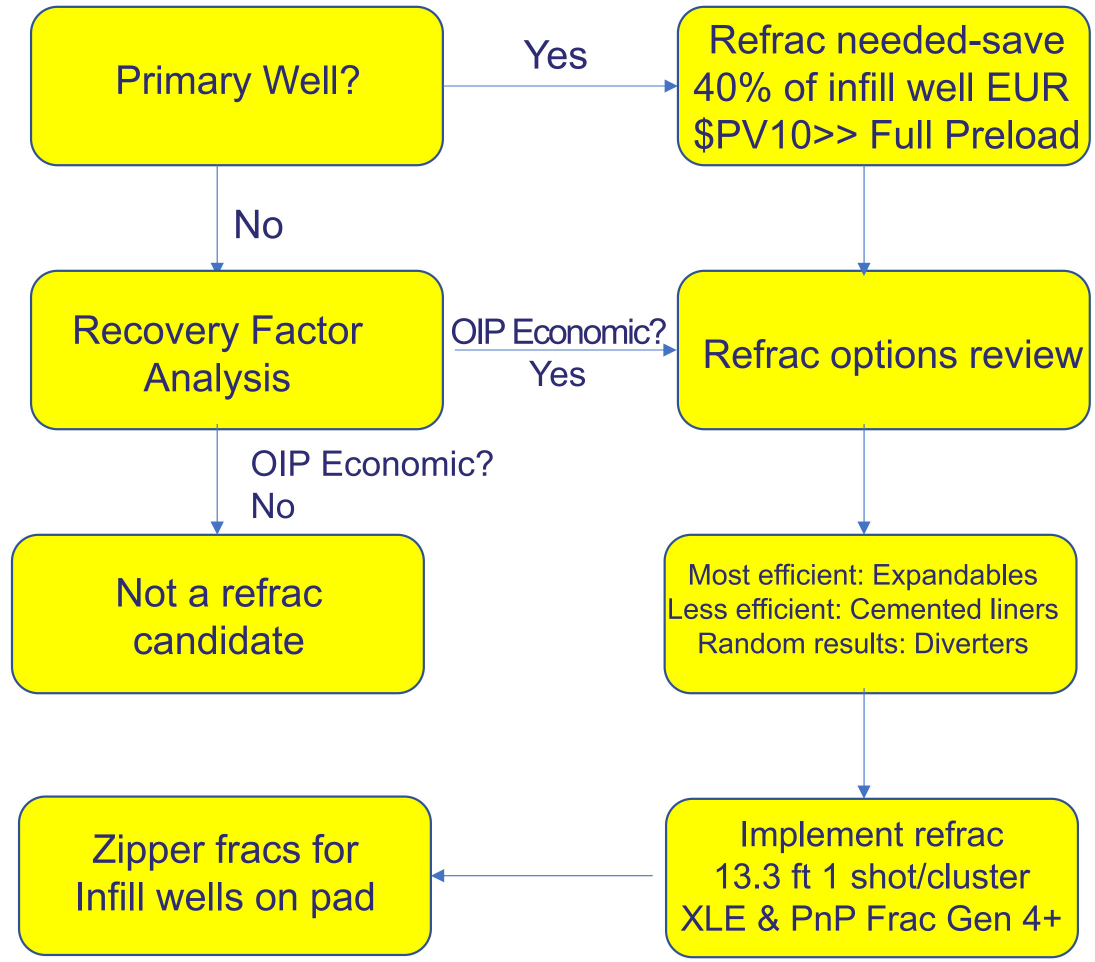
SPE 189880

Cluster Efficiency vs Effective Cluster Spacing



SPE 189880

Organic Shale Refrac Process Flow Chart

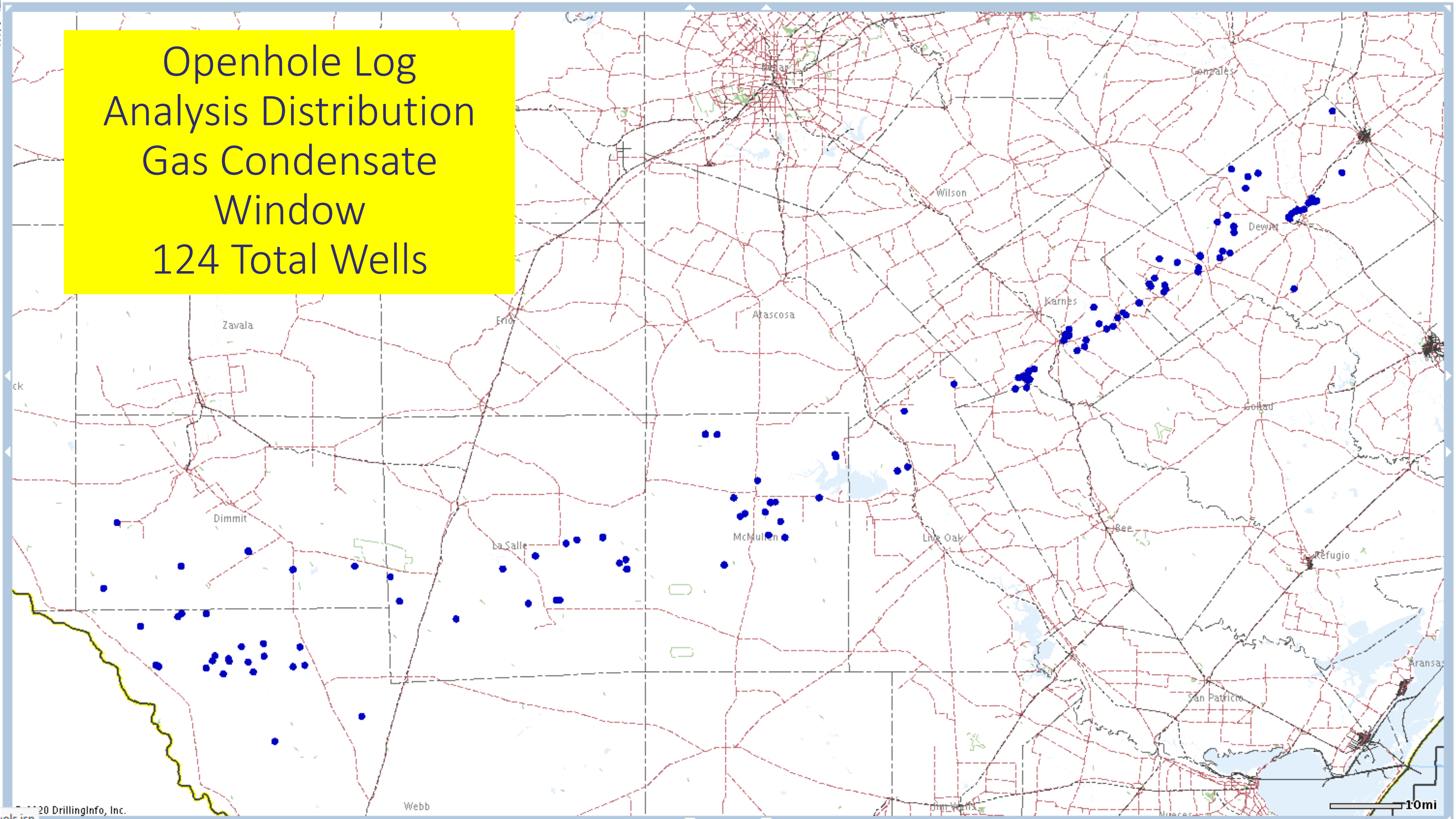


Refrac Candidate Optimization Work Flow

- Estimate the drainage height using a P3D hydraulic fracture model
- Estimate the original oil and gas in place for the drainage height from openhole log analysis and petrophysical property mapping
- Determine the expected recovery factor for a refrac using XLE, close cluster spacing, high proppant loading, and high fluid loading
- Calculate the remaining mobile hydrocarbons from the difference in expected recovery and current cumulative recovery
- Allocate these volumes on a monthly basis using type curve decline rates for the area
- Estimate the NPV and IRR for the refrac
- Execute the refrac using "best practices" to maximize cluster efficiency and SRV at the minimum possible cost

Part 1 Evaluating Refrac Opportunities in the Eagle Ford Condensate Window

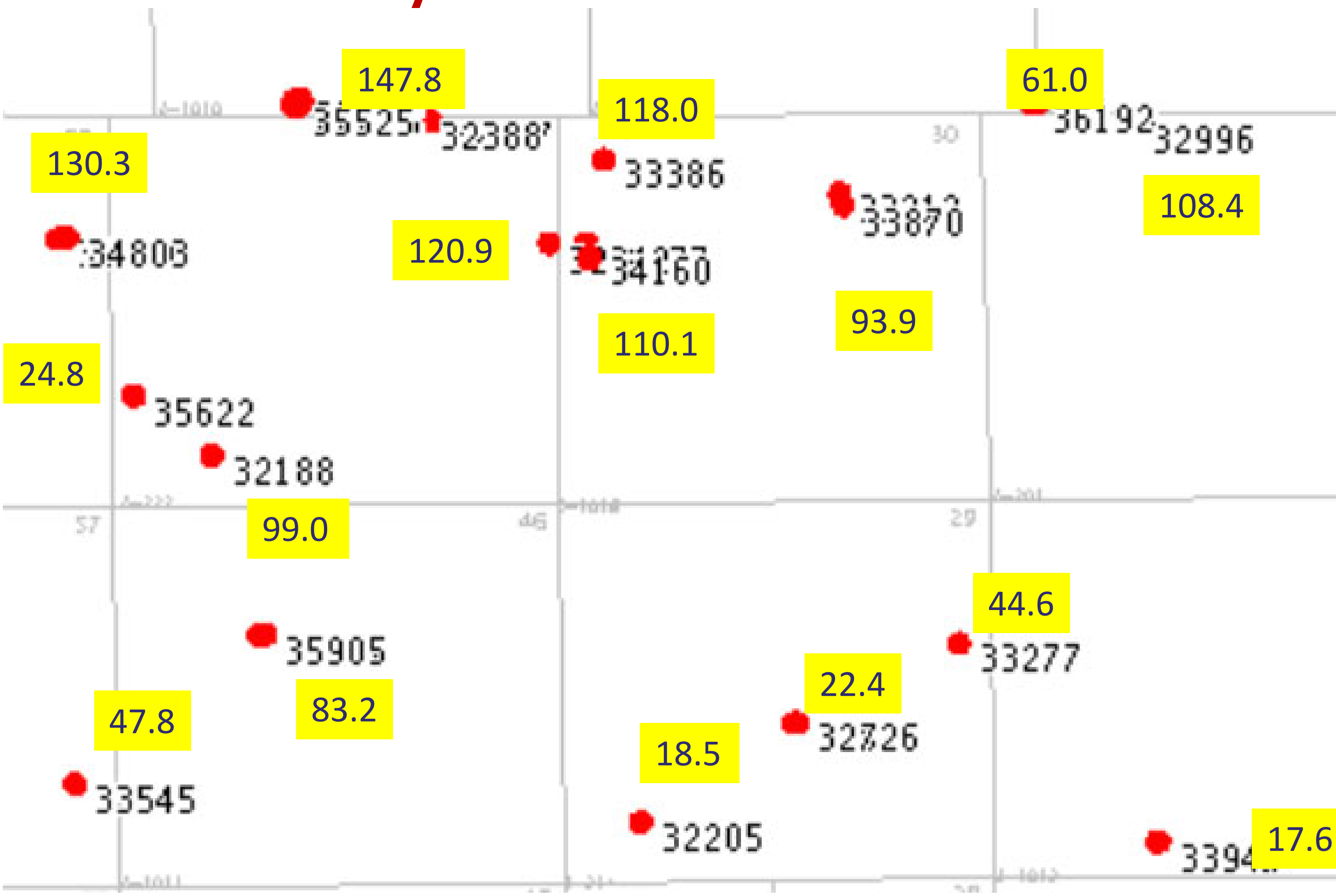
Openhole Log Analysis Distribution Gas Condensate Window 124 Total Wells



Why Focus on the Condensate Window?

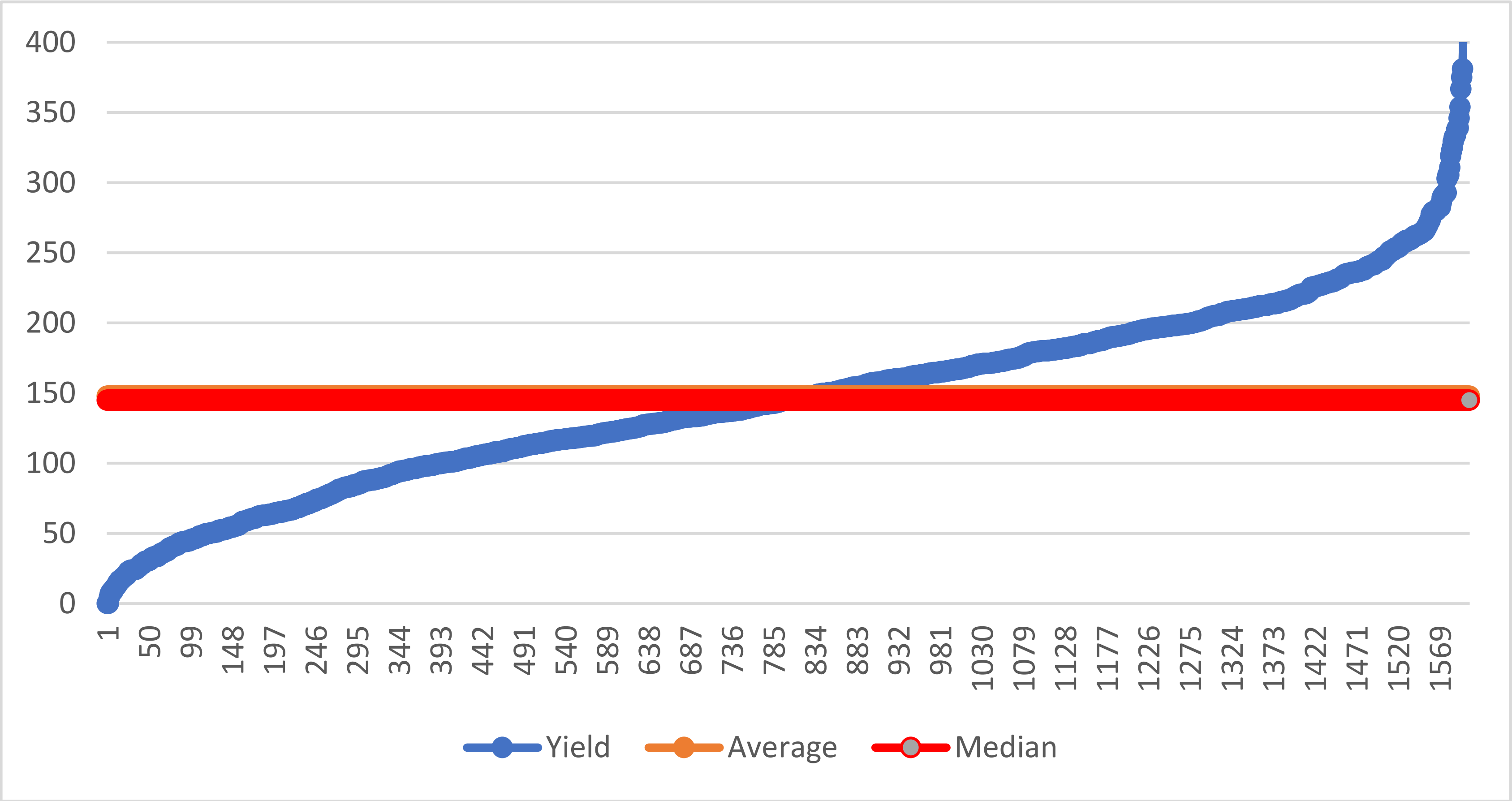
- Gas and gas condensate wells in Texas have individual well production, do not need operator data to find refrac candidates
- Modeling condensate well expected recoveries is more complex than liquids rich or dry gas wells, need to convert oil to MCFE values in the ground and apply yield profile specific to each well
- Yields are highly variable, new wells have large differences over short distances between wells
- Refracs have an established condensate yield and should have a much higher risk adjusted rate of return than new wells
- Current rigs are all updip of the gas condensate window most likely due to this added uncertainty and the current gas price strip
- Refrac economics in the condensate window are excellent even with the currently depressed price strips

La Salle County Condensate Window Yields



Yields variable but post refrac yields should be similar to pre-refrac yields

Karnes and Dewitt Condensate Yield Distribution

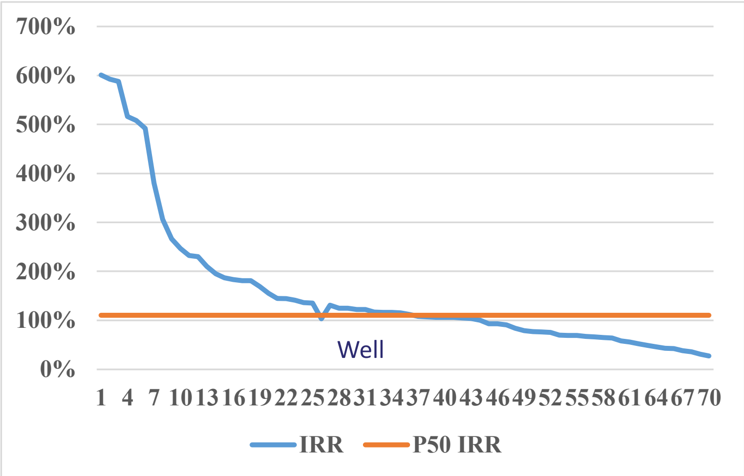


Condensate Window Study Workflow

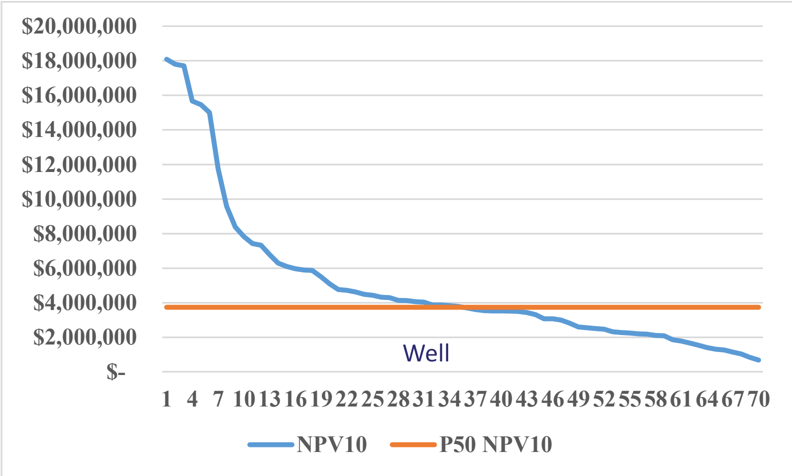
- Previous studies indicated that openhole well log control was critical to refrac candidate analysis due to significant reservoir heterogeneity
- Refrac candidates must have openhole log analysis coverage either very close by or surrounding the refrac candidate
- An inventory of all available openhole logs was obtained from TGS for 6 counties within the gas condensate window (Dewitt, Karnes, Live Oak, Bee, McMullen, La Salle, Dimmit, and Webb)
  - 124 total logs were identified, digitized, and analyzed
- Each operators wells were posted to determine if openhole log control was available for each of the prospective refrac candidates
- Only producers close to openhole logged wells or in-between control points were used

Eagle Ford Condensate Window Economics

IRR Distribution



NPV10 Distribution



	IRR	NPV10
P10	373%	$ 11,525,020
P50	110%	$ 3,743,821
P90	46%	$ 1,423,984

Price Strip Used for Economics

2/15/2021	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034 on
Nymex Oil	$ 56.66	$ 52.34	$ 49.74	$ 48.36	$ 47.71	$ 47.55	$ 47.62	$ 47.73	$47.92	$ 48.13	$ 48.13	$ 48.13	$48.13	$48.13
Nymex Gas	$ 2.95	$ 2.73	$ 2.55	$ 2.53	$ 2.56	$ 2.59	$ 2.62	$ 2.66	$ 2.72	$ 2.78	$ 2.82	$ 2.87	$ 2.92	$ 2.92

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EFS Condensate Window Candidates by Operator

Operator	Economic Candidates
Lonestar	10
Teal	9
CHK	8
Silverbow	6
BPX	5
SM ENERGY	5
Murphy	4
Sundance	4
XTO	4
DVN	3
GULFTEX	3
Penn Virginia	3
SN	2
AGERON	1
Churchill	1
Ensign	1
MRO	1

Eagle Ford Summary

- A methodology was presented to operators for evaluating remaining mobile gas and gas condensate in each refrac candidate in the Eagle Ford gas condensate window
  - Condensate well refracs have a significant advantage over new wells with the prior knowledge of the variable condensate yields and individual well production in the public databases
- 72 specific viable refrac candidates were identified with a complete petrophysical and economic analysis
- Required “best practices” to obtain these economics:
  - Expandable liners
  - Close cluster spacing
  - XLE with high proppant and fluid loadings

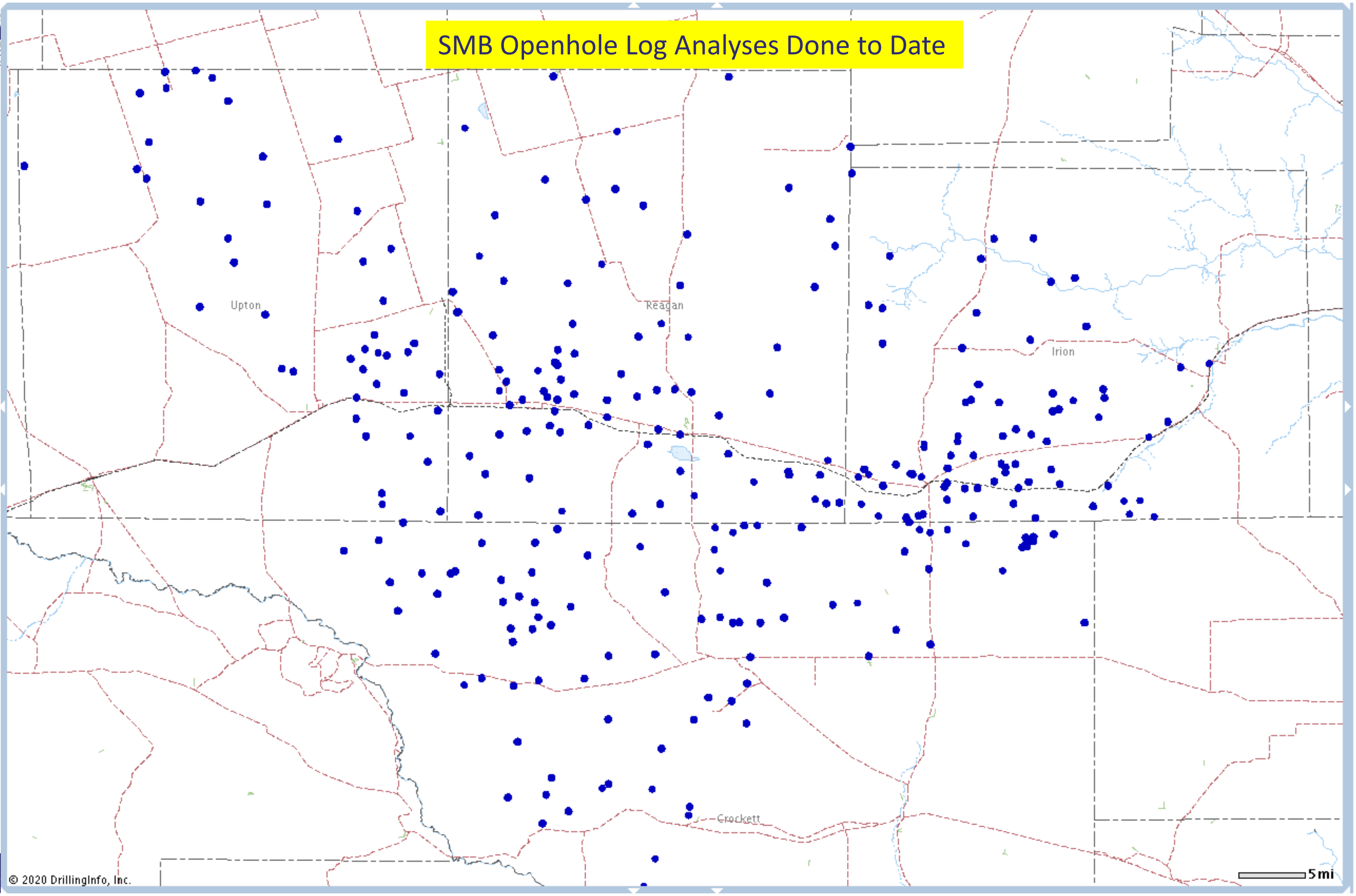
Part 2 Evaluating Refrac Opportunities in the Southern Midland Basin

Why Focus on the Southern Midland Basin?

- The Southern Midland Basin was the first area in the Permian Basin to employ horizontal multistage fracturing techniques in the Wolfcamp organic shale, first lateral in August 2009 with 111 ft cluster spacing
  - Until early 2015 cluster spacings averaged 56 ft in the area
- Studies have shown that recovery factors are directly related to cluster spacing and that they can be improved over 3x with close cluster spacings
- The area has a large number of University Lands wells where operators are required to release completion data which often contains cluster spacings
- This information is typically not routinely released by operators that do not have leases on University Lands

Southern Midland Basin Work to Date

- URTEC 2662 July 2020 documented recovery factor process, showed an average 13.7% recovery of oil in place between in-situ stress barriers
- The study involved the analysis of 196 producing wells and 36 openhole vertical well logs.
- Individual well production data was provided by the operators and allocation of lease production was thus not necessary.
- 302 total openhole logs have been analyzed to date in Reagan, Irion, Upton, and Crockett Counties
  - Oil in place and in-situ stress profiles generated for all wells
- 74 University Lands wells in area completed prior to Q1 2015 had cluster spacings reported, 43 of the 74 wells had economic OIP

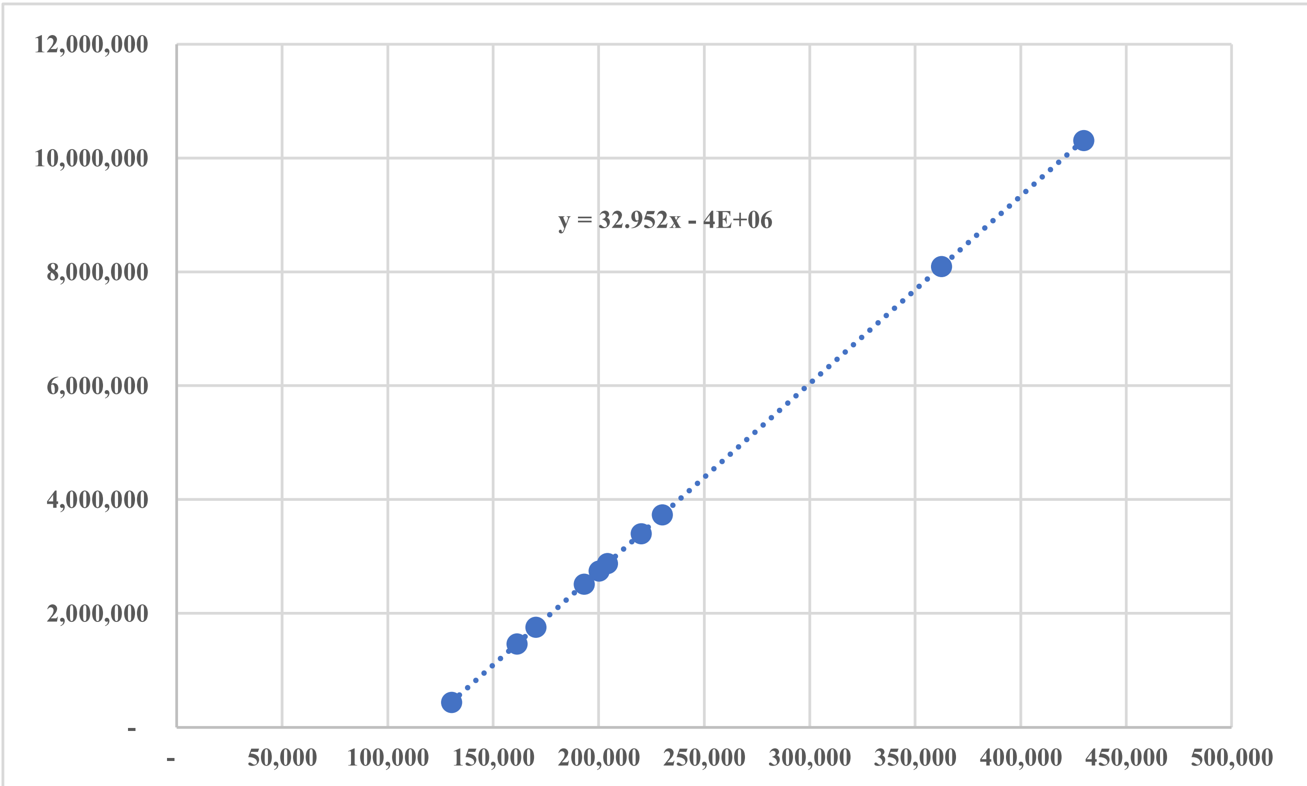

SMB Openhole Log Analyses Done to Date
Upton
Reagan
Irion
Crockett
© 2020 DrillingInfo, Inc.
5 mi

Southern Midland Basin OIP Analysis

- URTEC 2662 describes the work flow for estimating OIP and refrac EURs using petrophysics to estimate both OIP and in-situ stress distribution, producing "h" estimated with a P3D frac model
- A large number of candidates did not have clear stress layers and producing heights, thin barriers are difficult to see with log resolution and landing zones were not always clear
- A "quicklook" OIP estimation process is proposed to avoid these limitations and estimate an OIP from production data and an expected maximum recovery factor from the cluster spacing
- It is a maximum value since the modeling done to tie cluster spacing to recovery factor assumes 100% cluster efficiency
- The OIP can be estimated by dividing production (EUR or cumulative oil) by the maximum recovery factor
- Detailed economics can be run for a range of OIP values and both IRR and NPV10 can be empirically linked to the refrac EUR value to further streamline the process, a full analysis can be done for the top candidates from there

Wolfcamp Refrac EUR Oil vs NPV10

NPV10
$3.5 million
AFE



Refrac EUR (OIP-cumulative production)

2/15/2021	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033 on
Nymex Oil	$ 56.66	$ 52.34	$ 49.74	$ 48.36	$ 47.71	$ 47.55	$ 47.62	$ 47.73	$ 47.92	$ 48.13	$ 48.13	$ 48.13	48.13
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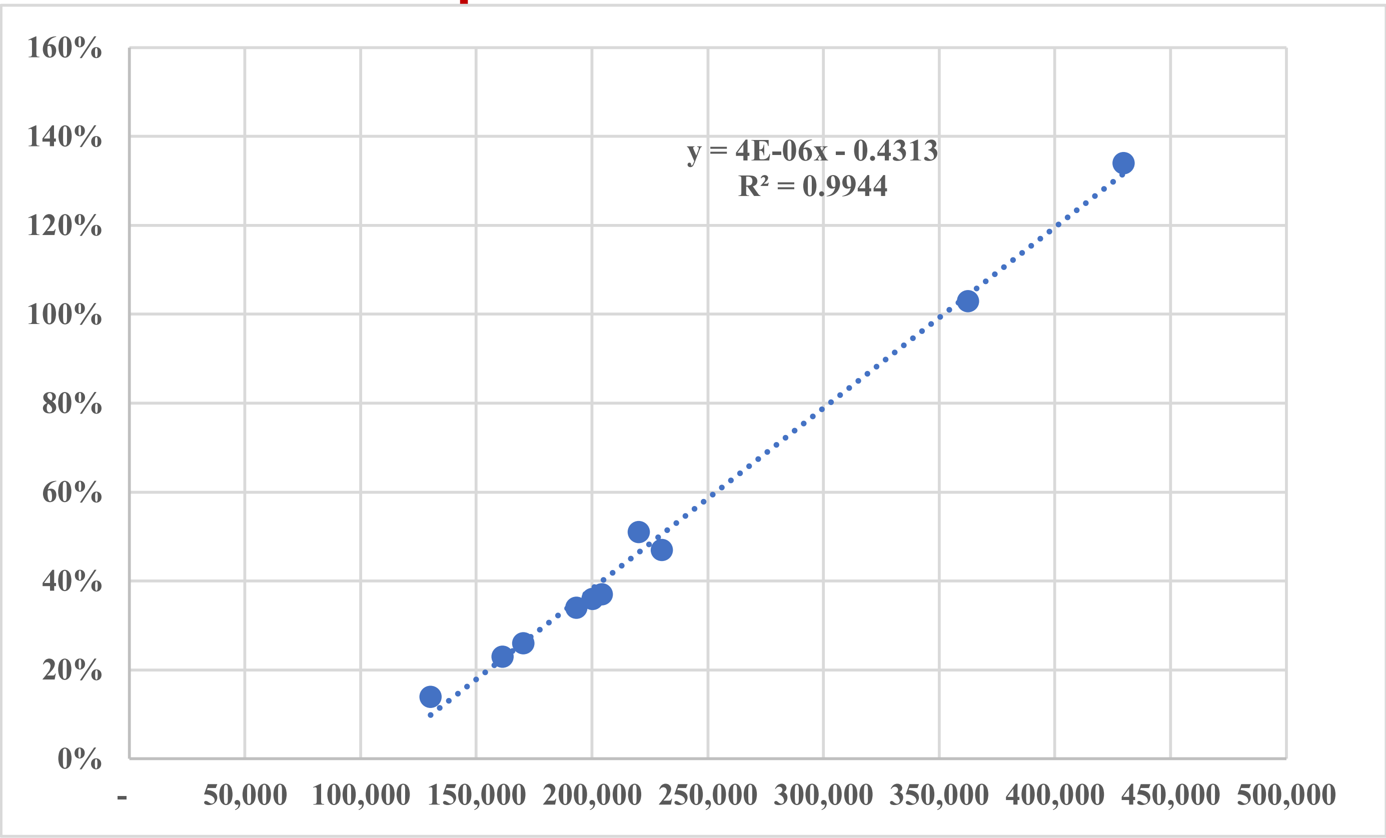
Wolfcamp Refrac EUR Oil vs IRR



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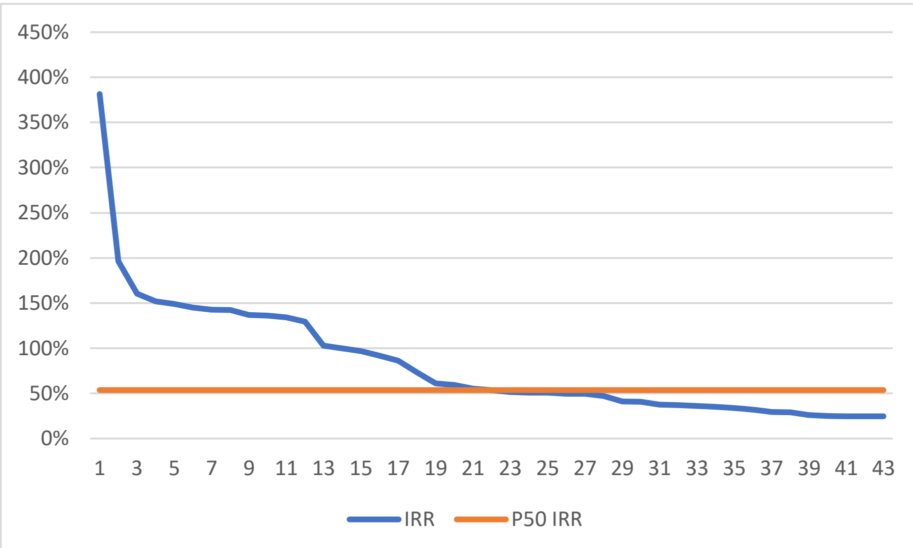
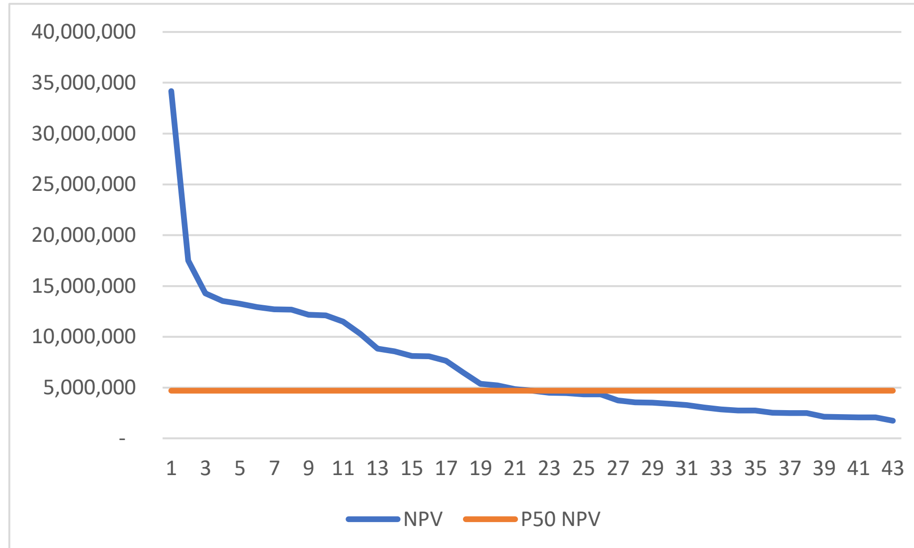
SMB Top 43 Refrac Candidates Economic Analysis

IRR Distribution



NPV10 Distribution



	IRR	NPV
P10	150.6%	$ 13,415,575
P50	53.7%	$ 4,701,122
P90	25.3%	$ 2,107,233

Price Strip Used for Economics

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SMB Operators with Pre Q2 2015 Completions

Wells	Operator
116	SABLE PERMIAN RESOURCES, LLC
32	SEM OPERATING COMPANY LLC
26	APACHE CORPORATION
20	LAREDO PETROLEUM, INC.
18	DIAMONDBACK E&P LLC
16	PARSLEY ENERGY OPERATIONS, LLC
15	PIONEER NATURAL RESOURCES COMPANY
11	DISCOVERY NATURAL RESOURCES, LLC
11	FORELAND OPERATING, LLC
9	EP ENERGY
5	BTA OIL PRODUCERS, LLC
5	CONCHO RESOURCES INC.
5	HUNT OIL COMPANY
5	TRIPLE CROWN RESOURCES, LLC
4	EARTHSTONE OPERATING, LLC
4	SM ENERGY COMPANY
3	TRP OPERATING LLC
3	ZARVONA ENERGY LLC
2	ENDEAVOR ENERGY RESOURCES, LP
2	EPIC PERMIAN OPERATING, LLC
2	OCCIDENTAL ENERGY COMPANY,INC.
1	DRIFTWOOD ENERGY OPERATING, LLC
1	EXXON MOBIL CORPORATION
1	GANADOR OPERATING, LLC
1	HENRY RESOURCES LLC
1	HIBERNIA RESOURCES III, LLC
1	LARIAT RESOURCES, LLC
1	QEP ENERGY COMPANY

28 total operators

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Southern Midland Basin Summary

- A methodology was presented to evaluate remaining mobile oil and refrac candidate economics in the Southern Midland Basin
- 43 specific viable refrac candidates were identified in the study based on expected increases in recovery factor for closer cluster spacing refracs
- P50 IRR for the 43 well sample 54% with a NPV10 of $4.7 million
  - These numbers are competitive with new well results at 2/3 the cost
- Required “best practices” for each well to fully realize estimates:
  - Expandable liners
  - Close cluster spacing
  - XLE with high proppant and fluid loadings

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Subsurface Consultants & Associates, LLC > Training > Course Listing > Refrac Candidate Selection, Execution and Performance Evaluation for Conventional and Unconventional Reservoirs

Refrac Candidate Selection, Execution and Performance Evaluation for Conventional and Unconventional Reservoirs

INSTRUCTOR: Robert 'Bob' Barba
DISCIPLINE: Engineering, Unconventional Reservoirs
COURSE LENGTH (DAYS): 2 Days
CEUS: 1.2 - 1.6
AVAILABILITY: In-House (Classroom) / Public (Online)

ATTEND AN UPCOMING CLASS:

April 13th and 14th, 2021 virtual online
4 hours each day $720 course fee

WHO SHOULD ATTEND: Engineers, managers, and geoscientists who want to maximize the probability of success and minimize surprises from a refrac program in unconventional or conventional reservoirs. Particular emphasis is placed on managing primary (parent) - infill (child) frac interactions within a drilling spacing unit to avoid EUR losses and to maximize the number of wellbores within the DSU. Refracs have been shown to be the most cost-effective method to maximize recovery within a DSU in both the primary and infill wells. “Best Practices” are presented to maximize productivity at the minimum cost possible from the primary and infill wells.

COURSE DESCRIPTION: Participants will learn a methodology that first accurately characterizes the reservoir properties to evaluate the effectiveness of the original hydraulic fracture treatment with production data. This enables a determination of the cause of poor production performance as a function of a poorly designed or executed completion or poor quality reservoir rock. If the remaining volumetric reserves are economic techniques are presented to effectively access these reserves with refracturing treatment(s). “Best practices” presented include recovery factor analysis, perforation cluster optimization using Extreme Limited Entry constrained by critical rate, and the use of expandable tubulars to minimize refrac costs. Innovative techniques such as single perforation hole clusters are discussed to more accurately gauge cluster efficiency. Treatments are designed to both maximize productivity from “new rock” and

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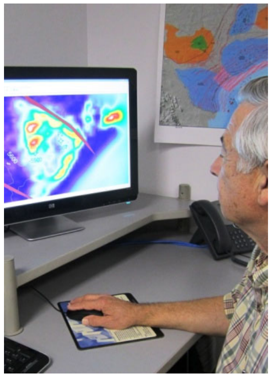

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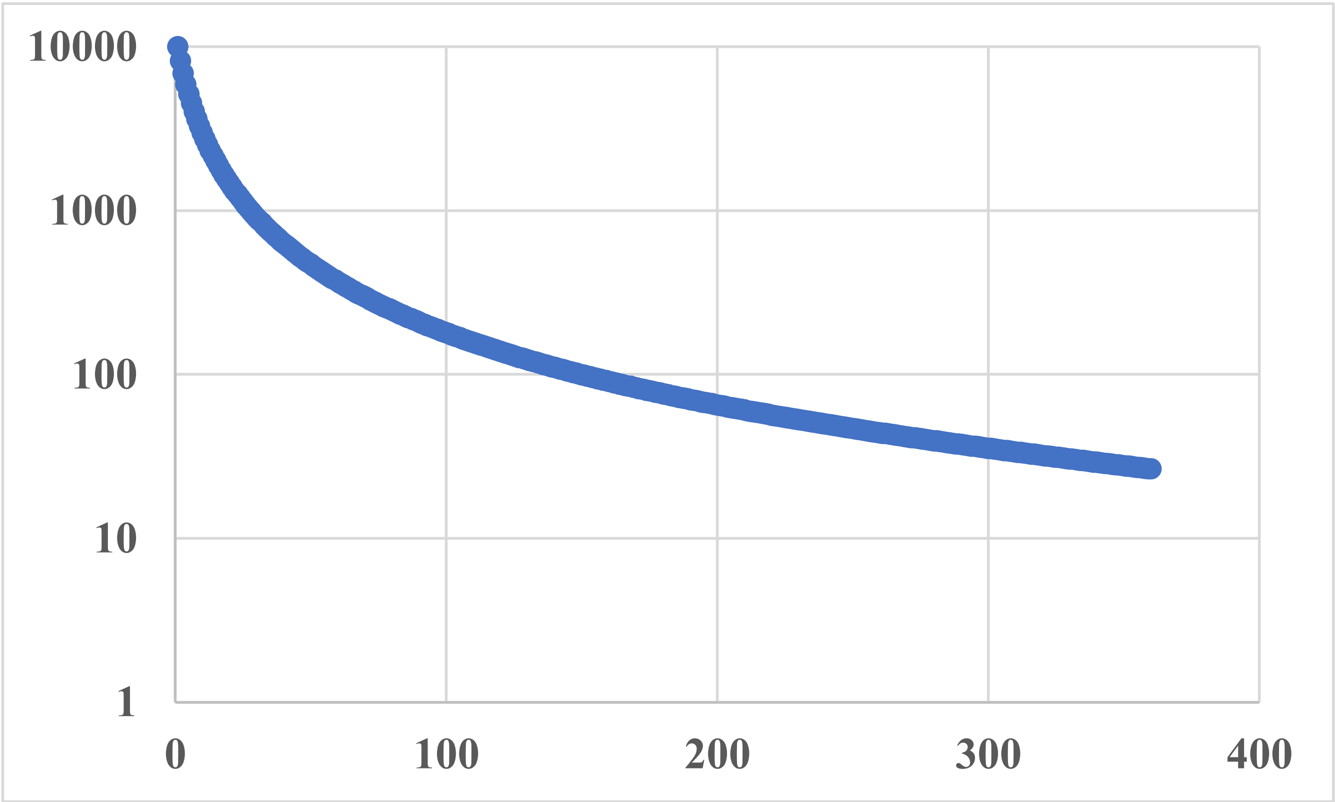
Backup Slides

Gas Condensate Reservoir Issues

- Volume of formation fluid will be 100% gas, need to evaluate all volumes and recoveries in terms of MCFE using a 5.8 to 1 ratio of gas to oil
- Gas volumes were calculated using the hydrocarbon pore volume adjusted with a specific formation volume factor (Bgi) for each well
- Type curve was developed from MCFE per month decline for multiple wells and the month to month decline % was averaged for all wells
- Cumulative production from the refrac candidate was used to determine the % of oil and gas on a MCFE basis the well has produced
- The initial MCFE rate was varied until a match was obtained with the remaining hydrocarbons from the difference between the 35% recovery value and cumulative production
- EURs are not useful other than to see if the refrac will only be accelerating recovery of existing reserves vs recovering incremental reserves

Eagle Ford Condensate Window Gas Type Decline

MCFE



For percentage decline by month analysis to allocate refrac EUR over time

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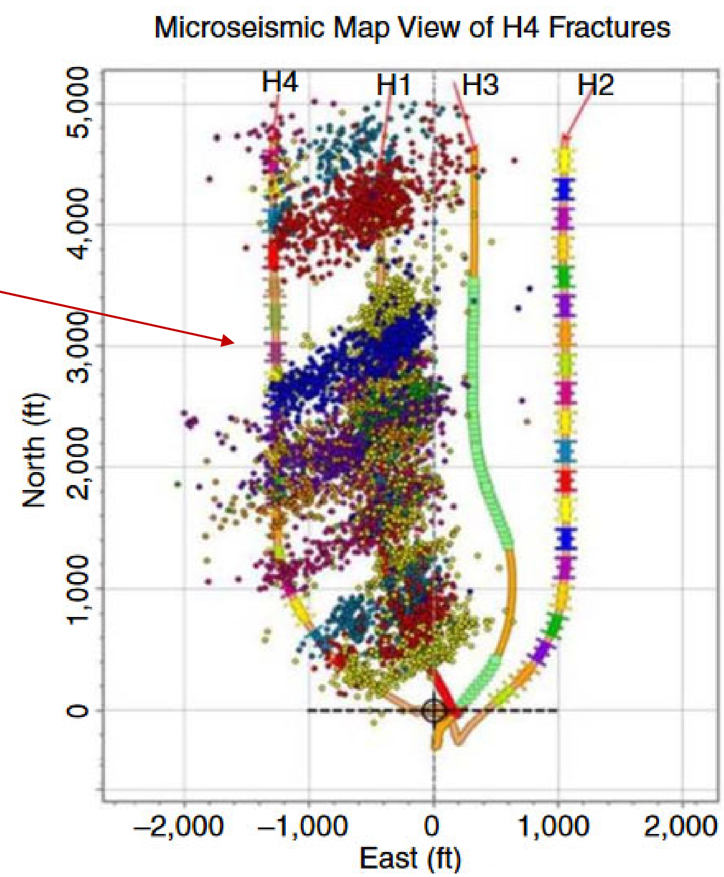
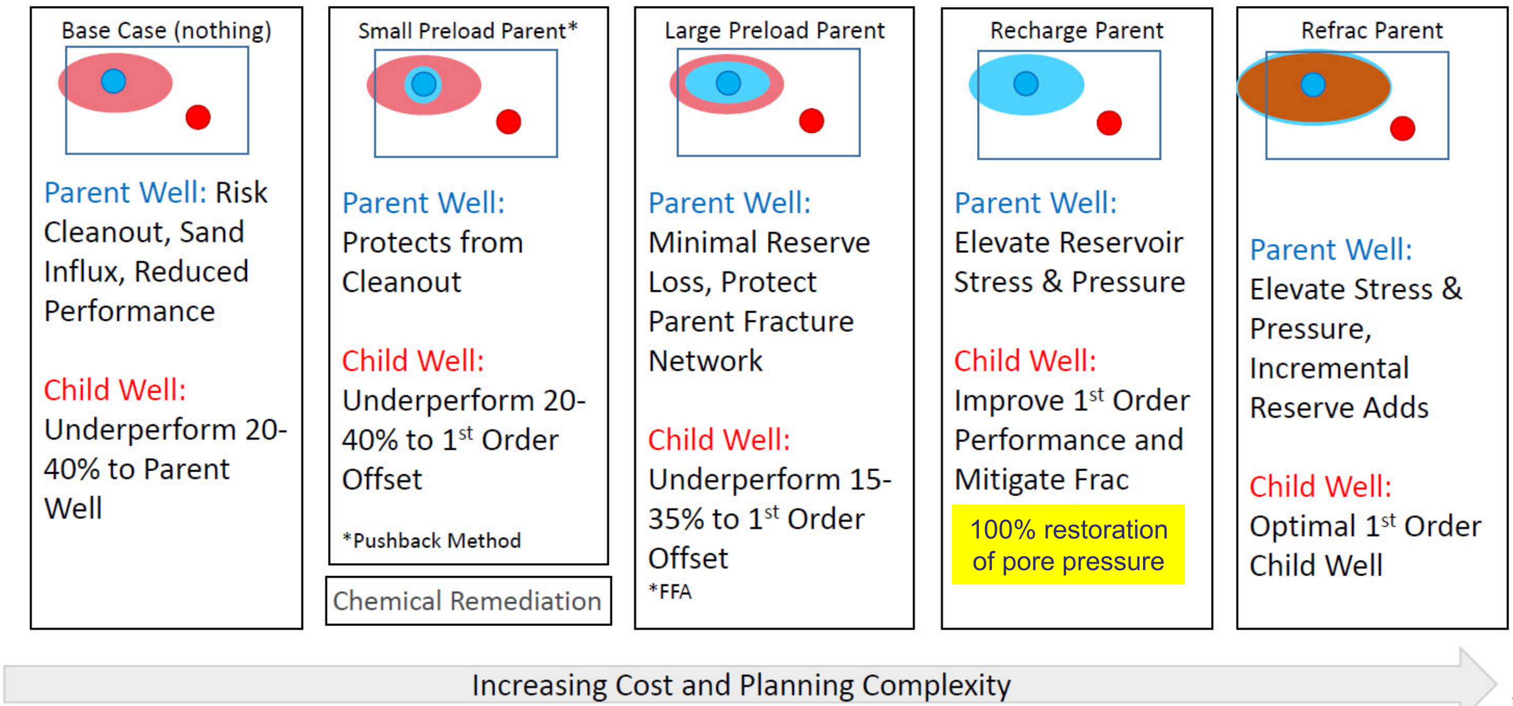
Asymmetric Frac 50% of OIP Unstimulated

- Infill/child well (H4) fracced and monitored with microseismic
- H1 primary/parent well depletion sink creates asymmetry
- Refrac or full recharge of H1 well would have mitigated or eliminated asymmetry



Depletion Mitigation Opportunities



Elliott, Brendan, Well Completions for Unconventional Resource Development Optimization and Parent Child Interaction Workshop, April 2019

Integrated Energy Services Inc